

## WHAT IS CLAIMED IS:

1. A method for driving a piezoelectric ink jet head composed of:

a pressure chamber filled with an ink;

5 a nozzle that communicates with the pressure chamber and has an ink meniscus formed therein from the ink that fills the pressure chamber;

10 a piezoelectric element of transverse vibration mode that contracts in the direction of plane when subjected to a drive voltage applied thereto; and

15 an oscillator plate that is stacked on the piezoelectric element so as to constitute a drive section and deflects so as to decrease the volume of the pressure chamber as the piezoelectric element contracts in the direction of plane when a voltage is applied thereto, so as to pressurize the ink in the pressure chamber and discharge an ink droplet from the tip of the nozzle, and

20 wherein the piezoelectric ink jet head is operated by combining

25 (A) the step of applying a drive voltage to the piezoelectric element so that the piezoelectric element contracts in the direction of plane and the oscillator plate deflects, thereby decreasing the volume of the pressure chamber, and

(B) the step of removing the drive voltage applied to the piezoelectric element so that the contraction of the

piezoelectric element in the direction of plane is canceled and consequently the deflection of the oscillator plate is canceled, thereby increasing the volume of the pressure chamber, thereby to discharge an ink droplet from the tip of the nozzle,

5 characterized in that the piezoelectric element is driven with a drive voltage waveform that has at least one of the following settings:

(a) time constant  $\tau_{UP}$  of rise of the drive voltage in the process (A) is set in a range that satisfies the relation of the expression

10 (i):

$$Ta/(-\ln 0.01) \leq \tau_{UP} \leq Ta/(-\ln 0.25) \quad (i)$$

with respect to the period Ta of the ensuing vibration of the drive section which is superposed on the vibration waveform of the volumetric velocity of ink in the head,

15 (b) time constant  $\tau_{DN}$  of fall of the drive voltage in the process (B) is set in a range that satisfies the relation of the expression (ii):

$$Ta/(-\ln 0.01) \leq \tau_{DN} \leq Ta/(-\ln 0.25) \quad (ii)$$

with respect to the period Ta.

20 2. A method for driving the piezoelectric ink jet head of claim 1, wherein the piezoelectric ink jet head is operated as follows:

a constant drive voltage is continuously applied to the piezoelectric element during a period of standby so that the 25 piezoelectric element is kept contracted in the direction of

plane and the oscillator plate continues to deflect, thereby to maintain the pressure chamber in a state of decreased volume and, during a period of forming a dot,

5 (1) the drive voltage is removed immediately before forming the dot so as to cancel the contraction of the piezoelectric element and relieve the oscillator plate deflection, thereby increasing the volume of the pressure chamber and pulling the ink meniscus in the nozzle back toward the pressure chamber, then

10 (2) the drive voltage is applied again so as to cause the piezoelectric element to contract and the oscillator plate to deflect, thereby decreasing the volume of the pressure chamber and discharge an ink droplet through the tip of the nozzle.

3. A method for driving the piezoelectric ink jet head of claim 1, wherein the piezoelectric ink jet head is operated as 15 follows:

the piezoelectric element in the state of standby is maintained in such a condition that drive voltage is not applied thereto, and

                  during a period of forming a dot,

20 (I) the drive voltage is applied immediately before forming the dot so as to cause the piezoelectric element to contract and the oscillator plate to deflect, thereby decreasing the volume of the pressure chamber, pushing the ink meniscus in the nozzle toward the tip of the nozzle and protruding the ink from the 25 tip of the nozzle like a column, then

(II) the drive voltage is removed again so as to cancel the contraction of the piezoelectric element and cancel the deflection of the oscillator plate, thereby increasing the volume of the pressure chamber and pulling back the ink column that 5 has been protruding from the tip of the nozzle into the nozzle, thereby separate an ink droplet.

4. A method for driving the piezoelectric ink jet head of claim 1, wherein the time constant  $\tau_{UP}$  of rise of the drive voltage in the step (A) is set in a range defined by a relation of the 10 expression (i-1):

$$Ta/(-\ln 0.05) \leq \tau_{UP} \leq Ta/(-\ln 0.25) \quad (i-1)$$

with respect to the period Ta.

5. A method for driving the piezoelectric ink jet head of claim 1, wherein the time constant  $\tau_{DN}$  of fall of the drive voltage 15 in the step (B) is set in a range that satisfies the relation of the expression (ii-1):

$$Ta/(-\ln 0.05) \leq \tau_{DN} \leq Ta/(-\ln 0.25) \quad (ii-1)$$

with respect to the period Ta.

6. A method for driving a piezoelectric ink jet head composed 20 of:

a pressure chamber filled with an ink;  
 a nozzle that communicates with the pressure chamber and has an ink meniscus formed therein from the ink that fills the pressure chamber;

25 a piezoelectric element that deforms when subjected to

a drive voltage applied thereto; and

an oscillator plate that is stacked on the piezoelectric element so as to constitute a drive section and deflects so as to decrease the volume of the pressure chamber as the 5 piezoelectric element deforms when a voltage is applied thereto, so as to pressurize the ink in the pressure chamber and discharge an ink droplet from the tip of the nozzle, and

wherein the piezoelectric ink jet head is operated by combining

10 (A) the step of applying the drive voltage to the piezoelectric element so that the piezoelectric element deforms and the oscillator plate deflects, thereby decreasing the volume of the pressure chamber, and

15 (B) the step of removing the drive voltage applied to the piezoelectric element so that the deformation of the piezoelectric element is canceled and consequently the deflection of the oscillator plate is canceled, thereby increasing the volume of the pressure chamber,

thereby to discharge an ink droplet from the tip of the 20 nozzle,

characterized in that the piezoelectric element is driven with a drive voltage waveform of which pulse width  $T_3$  of the drive voltage waveform between the rise of the drive voltage in the step (A) and the fall of the drive voltage in the step 25 (B) is set at an integral multiple of the period  $T_a$  of the ensuing

vibration of the drive section that is superposed on the vibration waveform of the volumetric velocity of ink in the head.

7. A method for driving the piezoelectric ink jet head of claim 6, wherein the piezoelectric ink jet head is operated as 5 follows:

a constant drive voltage is continuously applied to the piezoelectric element during a period of standby so that the piezoelectric element is kept deformed and the oscillator plate continues to deflect, thereby to maintain the pressure chamber 10 in a state of decreased volume and, during a period of forming a dot,

(1) the drive voltage is removed immediately before forming the dot so as to cancel the deformation of the piezoelectric element and relieve the oscillator plate of deflection, thereby 15 increasing the volume of the pressure chamber and pulling the ink meniscus in the nozzle back toward the pressure chamber, then

(2) the drive voltage is applied again so as to cause the piezoelectric element to deform and the oscillator plate to 20 deflect, thereby decreasing the volume of the pressure chamber and discharge an ink droplet through the tip of the nozzle, and (3) pulse width  $T_3$  of the drive voltage waveform from the fall of the drive voltage in the step (1) to the rise of the drive voltage in the step (2) is set at an integral multiple of the 25 period  $T_a$  of the ensuing vibration of the drive section.

8. A method for driving the piezoelectric ink jet head of claim 6, wherein the piezoelectric ink jet head is operated as follows:

the piezoelectric element in the state of standby is  
5 maintained in such a condition that drive voltage is not applied  
thereto, and

during a period of forming a dot,

(I) the drive voltage is applied immediately before forming the dot so as to cause the piezoelectric element to deform and the oscillator plate to deflect, thereby decreasing the volume of the pressure chamber, pushing the ink meniscus in the nozzle toward the tip of the nozzle and protruding the ink from the tip of the nozzle like a column, then

(III) the drive voltage is removed again so as to cancel the deformation of the piezoelectric element and cancel the deflection of the oscillator plate, thereby increasing the volume of the pressure chamber and pulling back the ink column that has been protruding from the tip of the nozzle into the nozzle, thereby to separate an ink droplet, and

20 (III) pulse width  $T_3$  of the drive voltage waveform from the rise of the drive voltage in the step (I) to the fall of the drive voltage in the step (II) is set at an integral multiple of the period  $T_a$  of the ensuing vibration of the drive section.